Hydrostatic Bearing Runner Leveling at Overseas 64-m-Diameter Antenna

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The hydrostatic bearing runners on the National Aeronautics and Space Administration/Jet Propulsion Laboratory 64-m-diameter antennas must be set to flatness tolerances which represent a major field alignment problem. A method, based on the use of an electronic level, was successfully employed in setting the runners for the new 64-m-diameter antennas at Deep Space Station 43 (Australia) and Deep Space Station 63 (Spain).

I. Introduction

The alignment of the hydrostatic bearing runners on the 64-m-diameter antennas is very difficult because of the physical size of the runners and the strict flatness requirements placed on the runner by the antenna pointing and bearing operational requirements. This article describes the methods which were developed and used on the antennas at Deep Space Stations (DSS) 43 and 63.

II. Hydrostatic Bearing Runner

The hydrostatic bearing runner (Fig. 1) is a steel ring 23.4 m (920.25 in.) in diameter at the centerline, 112 cm (44 in.) wide, and 17.8 cm (7 in.) thick. It is made up of 11 segments, with connections between adjacent segments made up tight before alignment is accomplished. Each segment has six leveling lugs each along the inside and outside edges, placed in radial pairs. The segments are supported on studs welded to steel embedded in the pedestal, which support the leveling lugs. Nuts on these studs permit local adjustment of the runner elevation.

The following requirements were established for the flatness of the hydrostatic bearing runner as installed:

(1) The runner must be flat within 0.076 mm (0.003 in.) over any 1.52-m (60-in.) length. Each pad is 1.52 m long, and this requirement relates to the maintenance of the proper film height and pressure patterns under the pad. Compatible tolerances for the flatness of the runner as machined were established on the manufacturing drawings.

(2) The mean plane of the runner must be within 20 arc seconds of being level with local gravity, and the entire runner must be within ±0.25 mm (0.010 in.) of the mean plane. These requirements establish the verticality of the azimuth axis of the antenna and limit the wobbling of the antenna as it rotates in azimuth. A value of 20 arc seconds is equivalent to an elevation difference across a diameter of the runner, at the runner cross section centerline, of 2.3 mm (0.090 in.).

(3) Any radial line on the top surface of the runner must be within 10 arc seconds of an arbitrary datum, which in turn must be within ±48 arc seconds of local gravity. This requirement is to limit the twist in the runner seen by the pads as the antenna moves in azimuth. The 48-arc-second requirement permits an elevation difference of 2.5 mm (0.100 in.) between the inside and the outside edges of the runner, and the 10-arc-second tolerance represents an elevation difference of 0.050 mm (0.002 in.).

III. Leveling the Runner

The initial intent on the overseas antennas was to survey points on the top surface of the azimuth bull gear on a radial line with each pair of leveling lugs on the runner, using an N3 level mounted at the center of the antenna. The runner was then to be set with reference to these points using the pintle radial tooling assembly, measuring from the bull gear to the runner. In practice it was found that this was not a satisfactory arrangement because of errors inherent in surveying the bull gear surface at a range of 11 m (35 ft.) and because temperature changes in the aluminum members of the pintle radial tool necessitated frequent recalibration at a reference point to maintain satisfactory accuracy.

To avoid these problems, special alignment tools, based on the Talyvel electronic level, were constructed (Fig. 2). These consist of a T-shaped structure with a Talyvel level and a bubble cross level mounted near the center. Adjusting screws are located at each end of the leg of the T and of the cross bar. When the level was set on the runner, one arm of the cross bar hung away from the runner and the level was supported on the three remaining screws (Fig. 3). A small movable counterweight assured that the level was stable when so set and would not fall off the runner.

One level (Fig. 4) was made 1.17 m (46 in.) long, about midway between the chordal distance between the leveling lugs on the inside and between those on the outside. The other was 0.55 m (21¾ in.) long, which related to the chordal distances between the lugs across the joints. The longer level had an additional adjusting screw, placed in the leg about 1 m (40 in.) from the cross arm. This permitted the use of the level to measure across the runner, from inside to outside. When the level was used in this way, 0.32-cm (0.125-in.) ground shims were placed under supporting screws to assure that the reading was not affected by the unintentional contact of one of the other screws.

The level was adjusted by setting it along the edge of the runner and adjusting the supporting screw at the end of the cross arm to set the cross level within about 30 arc seconds of level (Fig. 3). Tests had indicated that cross level errors up to about one arc minute did not affect the accuracy of the Talyvel level. By reversing the position of the level on the runner, the two screws on the cross arm could be set independently. The screw at the foot of the T was then adjusted so that the level gave the same reading, with opposite signs, when reversed (plunged) on the same two points. This adjustment, which assured that zero on the level represented a true level, was primarily used to assure that the Talyvel readout stayed on scale in subsequent readings. The Talyvel readout was in arc seconds directly, with one arc second being equivalent to an elevation difference of 0.0056 mm (0.00022 in.) on the long level and 0.0024 mm (0.0001 in.) on the short.

All runner adjustments were made at night, to avoid the thermal distortions of the runner due to heat from the sun. In using the levels, leveling points approximately 5 cm (2 in.) in from the edge at each lug were established, and all surveys were with respect to these points. The long level span was a little greater than the distance between these points on the inside, and a little less on the outside. Because of the flatness requirement held in machining the runner surfaces, the error in being slightly off the survey points was considered negligible. Data were recorded in terms of arc seconds for each level, with closures and correction being made in arc seconds. The transition to centimeters or inches was then necessary only in the last step after a survey was complete.

At DSS 43, the outside leveling points were set using the T levels, and the inside points were set using the cross level portion of the pintle radial tool, which was not affected by the problems previously described. In the use of the T levels, the elevation difference between adjacent leveling points was determined by taking readings with the level in a forward and reverse position, with the elevation difference determined from the mean of the two readings. This procedure eliminated the need for frequent zero checks of the level and provided a quick check for gross inaccuracies, which were indicated if the absolute value of the forward and reverse readings had a large difference. After the runner was set it was surveyed by running a traverse completely around the outside of the runner and measuring inner elevations from the related outside point. Closure on the traverse was 0.11 mm (0.0044 in.).

The final survey data showed a total elevation range, inside and outside, of 0.24 mm (0.0095 in.). Elevation difference across the runner ranged from 0.06 to 0.15 mm (0.0025 to 0.006 in.), with the inside always low and a maximum out of flatness, determined by the runner twist from one pair of survey points to the next, of 0.075 mm (0.003 in.). Thus the runner, as leveled, and before grout placement or loading, met each of the requirements previously listed.

At DSS 63, the pintle radial tool was used only for preliminary leveling. In final leveling, adjustments were made to the T levels directly. After the first stage of leveling was complete on a segment, a traverse was made around the segment and appropriate adjustment made. A final survey, consisting of two passes around each segment, was made, together with a similar traverse around the four lugs adjacent to each joint. Again the traverses, closing within 0.051 mm (0.002 in.), were corrected for closure and the two traverses averaged to determine the final elevation.

The T levels were built by JPL and used jointly by JPL and the contractor. The Talyvel levels were little affected by the frequent movement and maintained excellent repeatability. The original levels made on site in Australia (shown in Fig. 2), were somewhat heavy to use, and the counter weight tended to jar the Talyvel level if not moved with care. The improved levels made at JPL (shown in Figs. 4 and 5) were about half the weight of the original levels, and the counterweight was arranged to eliminate the jarring stop. With these instruments, a full traverse of the runner could be accomplished in about 3 hours. The overall adjustment of the runner took approximately one week.

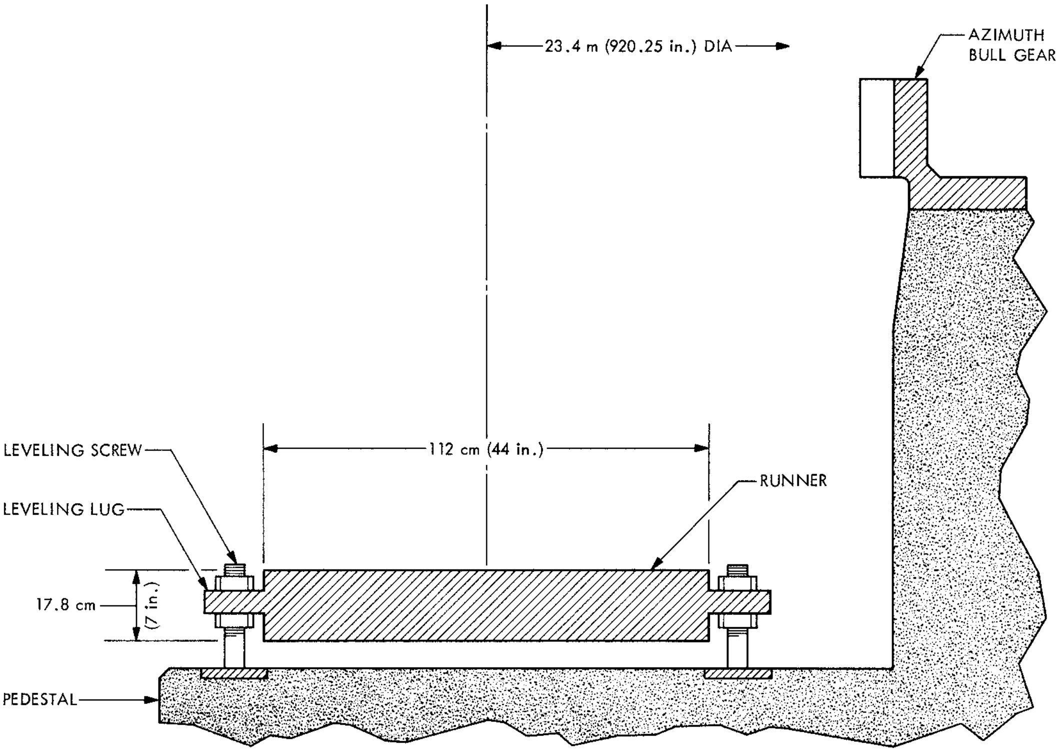

Fig. 1. 64-m-diameter antenna hydrostatic bearing runner

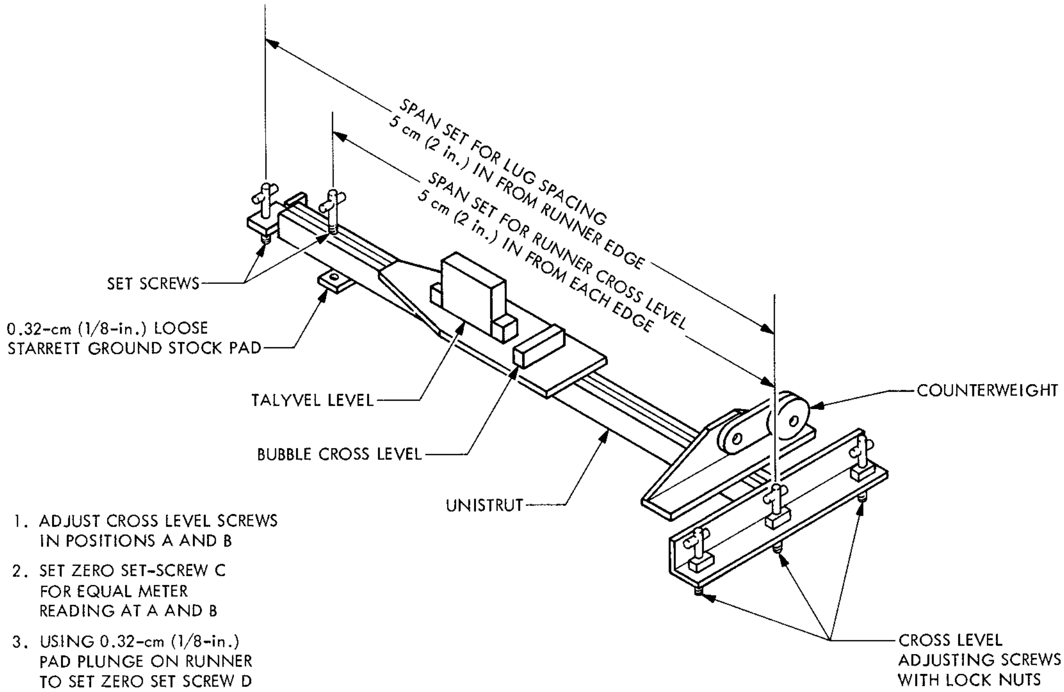

Fig. 2. Runner level check tool

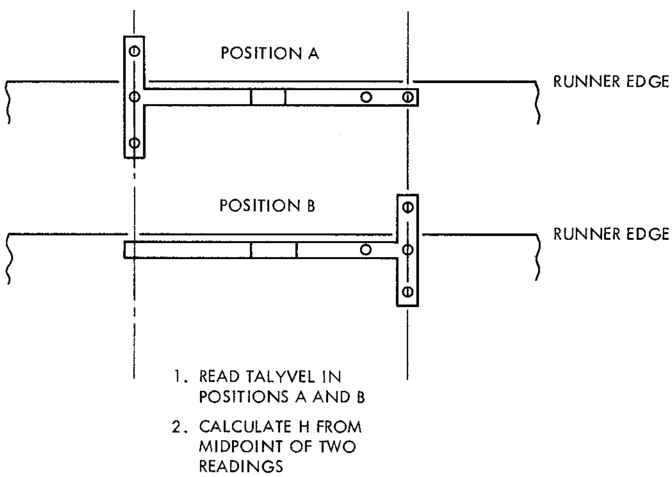

Fig. 3. Level positioning on runner

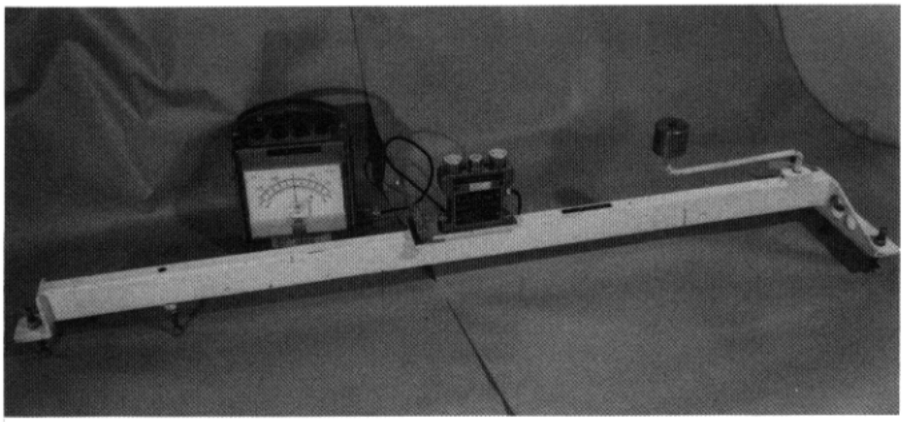

Fig. 4. Long runner alignment tool

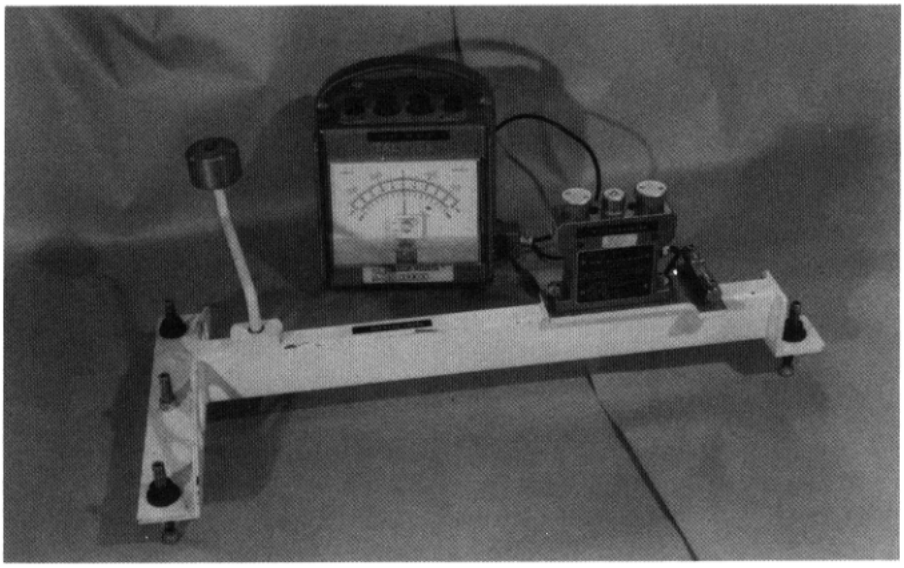

Fig. 5. Short runner alignment tool